Lower Potomac River Basin Summary

Final Version for 1985-2002 Data
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Lower Potomac Basin Characteristics

The Lower Potomac River basin drains 730 square miles, including portions of Charles, Saint Mary's, and Prince George's Counties. The river is entirely tidal in the basin. Larger water bodies include Mattawoman Creek, Breton Bay, and the Wicomico and Saint Mary's Rivers. One of the largest great blue heron rookeries on the east coast is located on Nanjemoy Creek. The basin is located solely within the Coastal Plain physiographic province.

The 2000 census population for the Lower Potomac River basin was 181,000. Larger cities in the basin include La Plata and Leonardtown.

Land use in the basin is 60 percent forest/wetlands, 24 percent agricultural, and 16 percent urban (Figure LPR1).

As of 2002, the most significant contributor of nitrogen in the Lower Potomac River basin was agriculture (38 percent) (Figure LPR3). Following that were point sources and urban sources (22 percent each). For phosphorus, the largest contributor was agricultural sources (41 percent), followed by urban sources (34 percent), mixed open areas (14 percent), and point sources (8 percent) (Figure LPR4). Agriculture was the dominant source of total suspended solids (68 percent) followed by forested areas (17 percent) and urban sources (11 percent) (Figure LPR5).

Figure LPR1 – 2000 Land Use in the Lower Potomac River Basin.

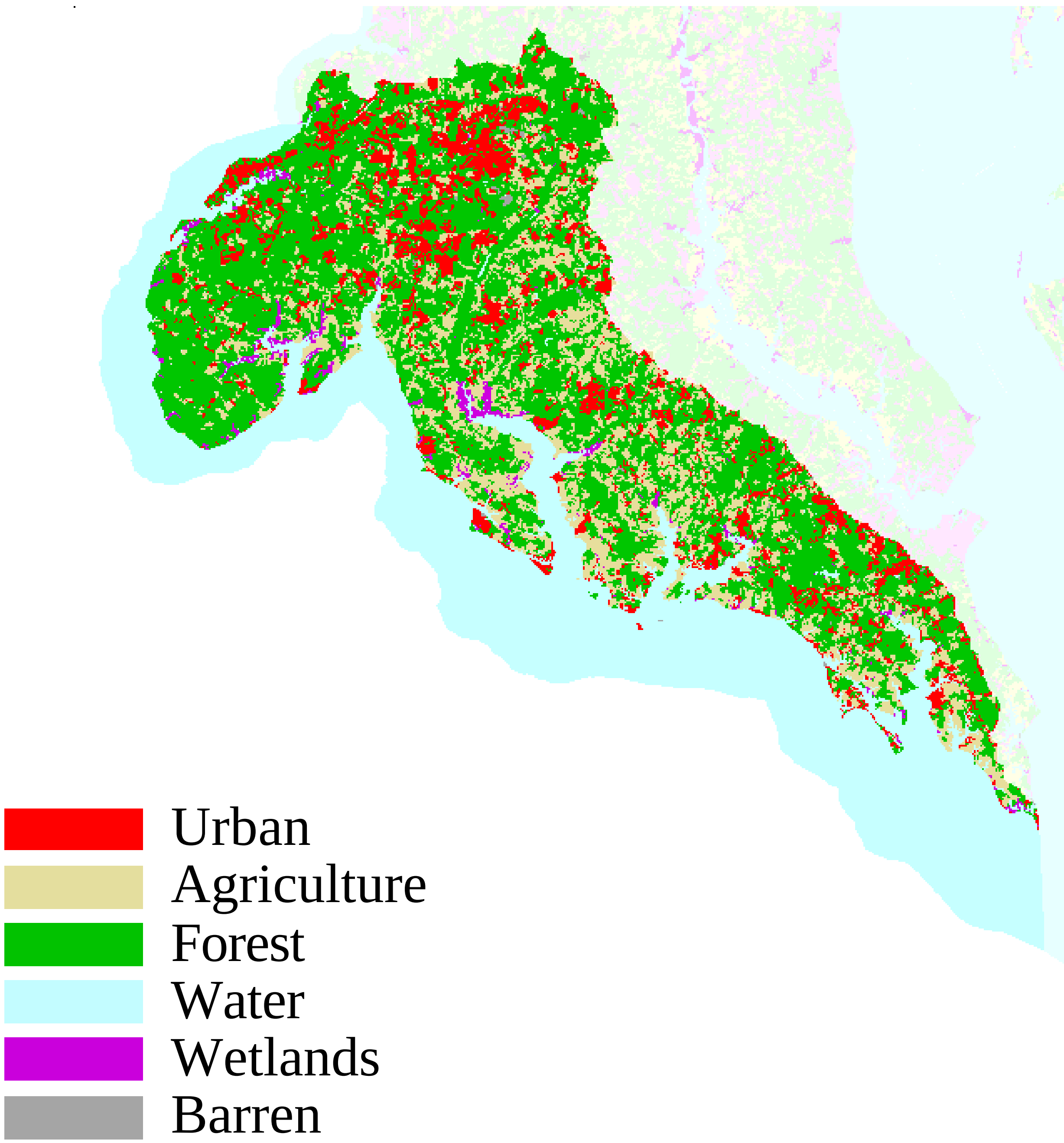


Figure LPR2 – Wastewater Treatment Plants in the Lower Potomac River Basin.

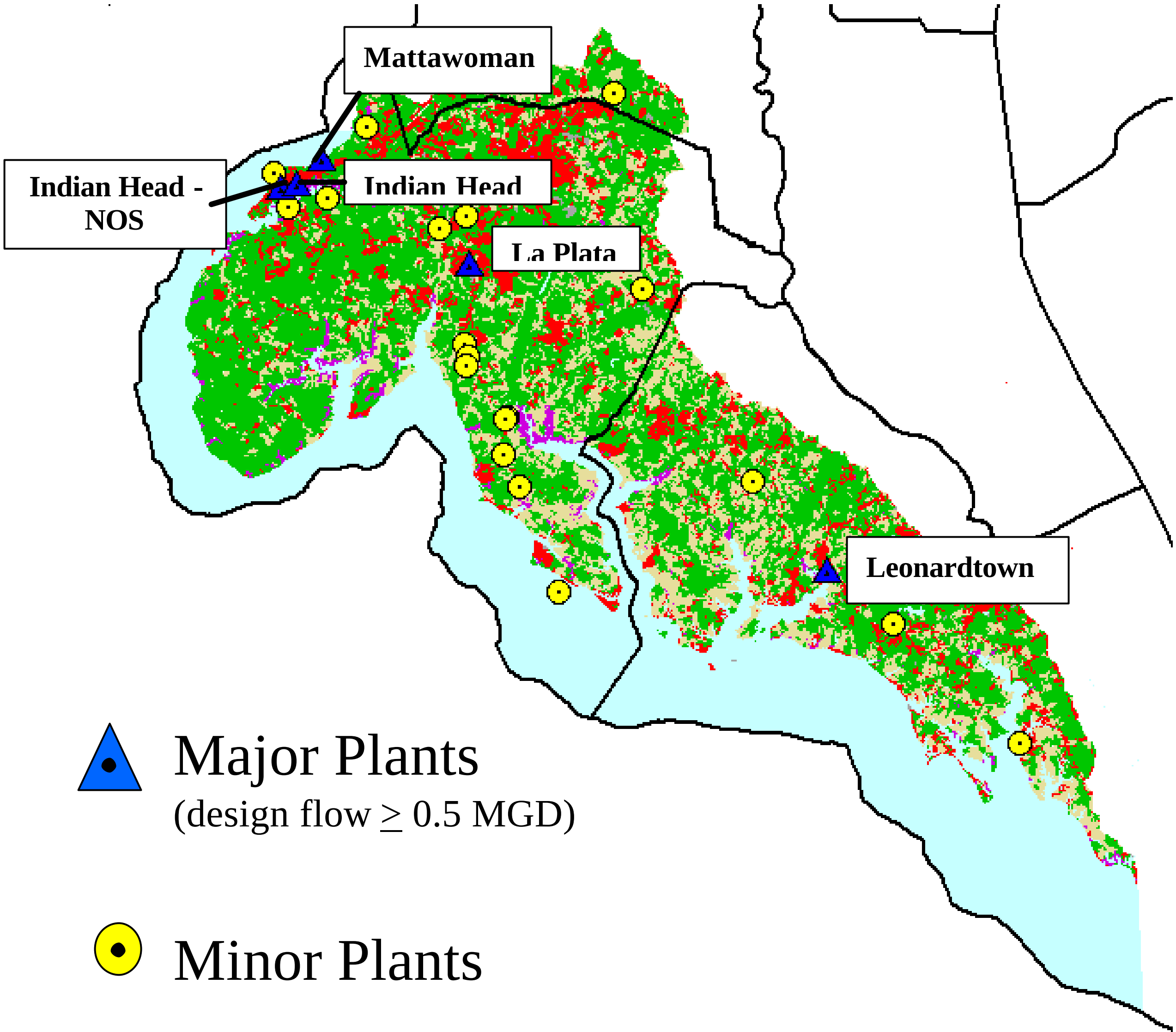


Figure LPR3 – 1985 and 2002 Nitrogen Contribution to the Lower Potomac River Basin by Source.

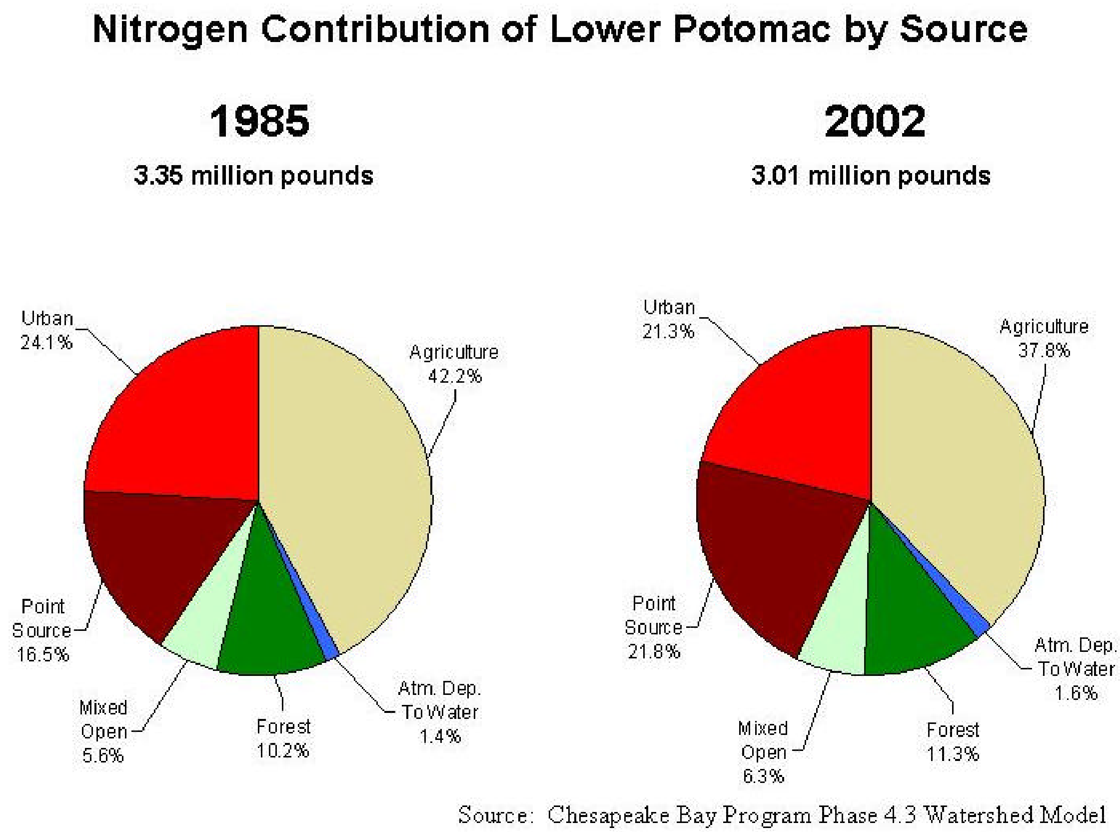


Figure LPR4 – 1985 and 2002 Phosphorus Contribution to the Lower Potomac River Basin by Source.

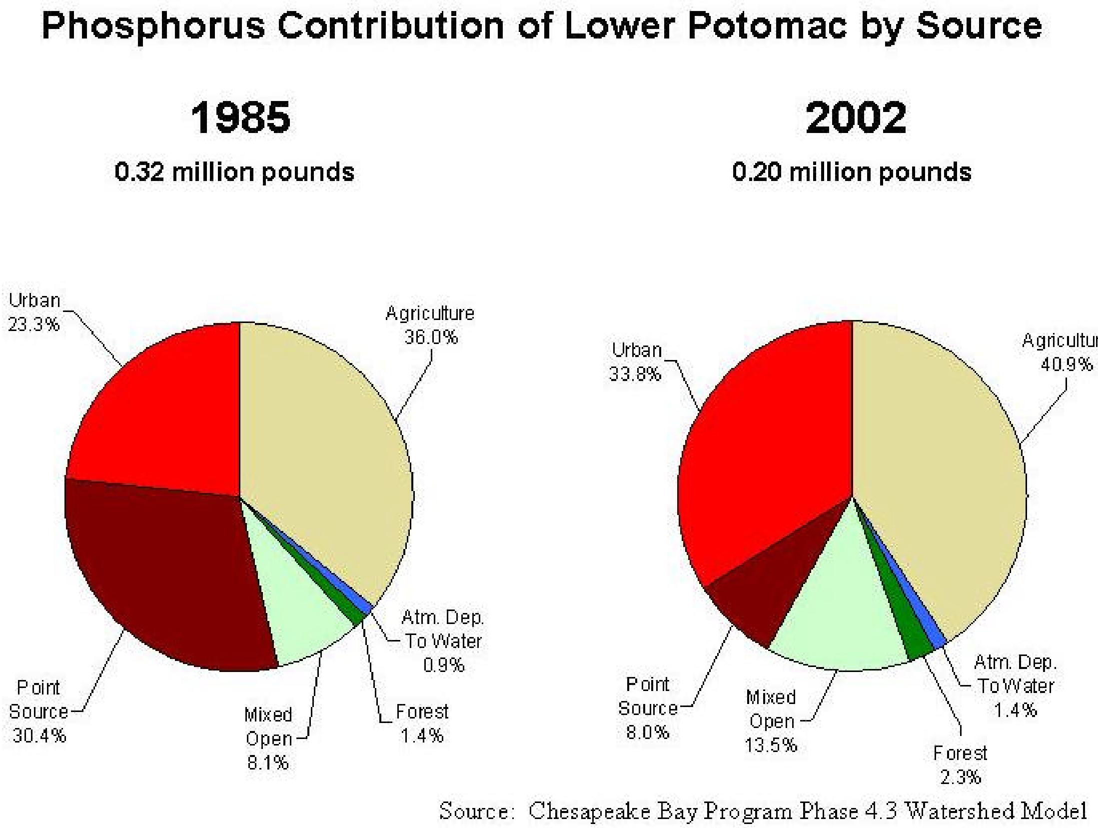
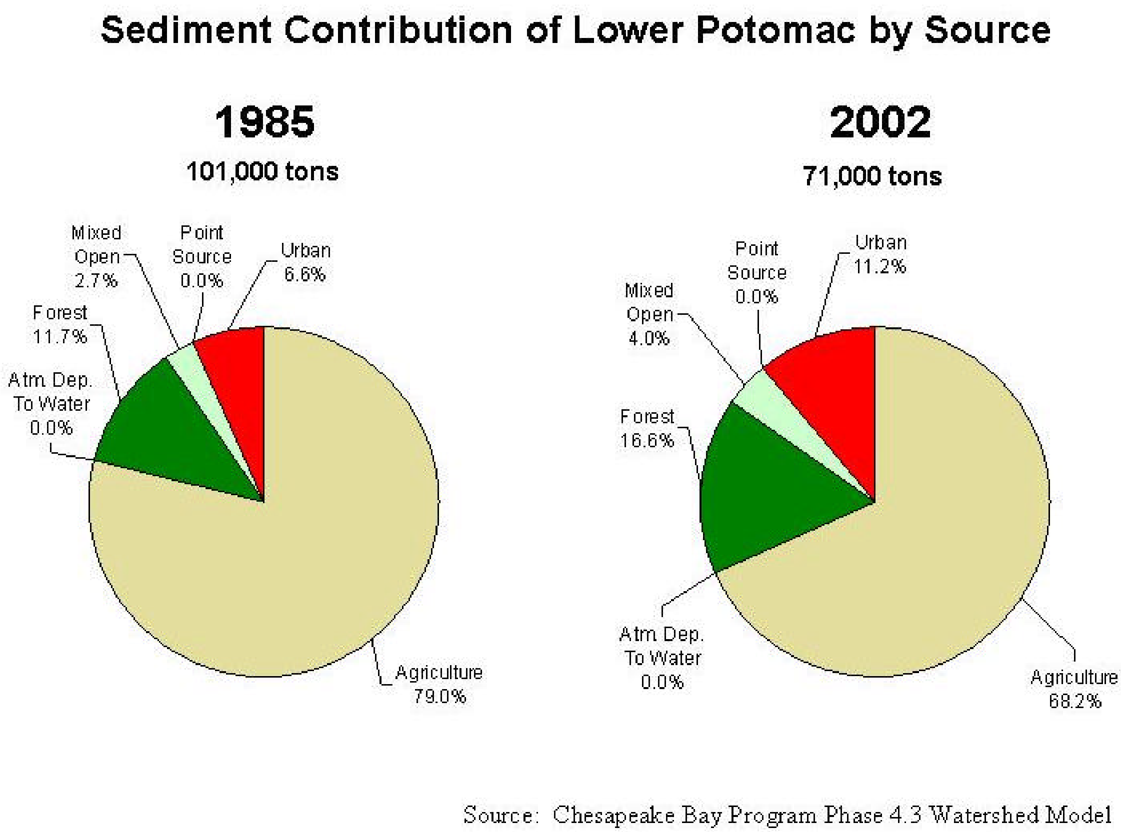


Figure LPR5 – 1985 and 2002 Total Suspended Solids Contribution to the Lower Potomac River Basin by Source.



Overview of Monitoring Results

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at: **http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html** MBSS also reports stream quality information summarized by county at: **http://www.dnr.state.md.us/streams/mbss/county_pubs.html** In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss**

Information on Prince George's County water quality monitoring and stream assessments are available at: **http://www.co.pg.md.us/Government/AgencyIndex/DER/PPD/Environment_Protection/water_quality.asp?h=20&s=40&n=50&n1=150**

Water quality information collected by Maryland's volunteer Stream Waders is available at: **http://www.dnr.state.md.us/streams/mbss/mbss_volun.html**

Long-term Water Quality Monitoring

Total nitrogen concentrations declined (improved) at all nine stations. Water quality status varied from poor to good, though most stations were fair.

Total phosphorus declined (improved) at three stations. No trends were detected at the remaining six stations. Water quality status ranged from poor to good. Most stations in the basin were rated good.

Despite improvements to area wastewater treatment plants, and double digit decreases in nitrogen at most stations, trends in algal abundance were increasing (degrading) at four stations. No trends were observed at the remaining five stations. Water quality status ranged from poor to good, with several stations rated as good.

Trends in total suspended solids decreased (improved) at two stations and increased (degraded) at one station. Water quality status was either fair or good. The degrading trend in the lower estuary may have resulted from increased re-suspension of sediments.

Water clarity, as measured with a Secchi disk, increased (improved) at one station and decreased (degraded) at another station. Water quality status ranged from poor to good.

Summer (June through September) bottom dissolved oxygen increased (improved) at one station. No trends were detected at the remaining six stations where bottom dissolved oxygen is measured. Water quality status ranged from poor (lower estuary) to good (upper estuary).

Figure LPR6 – Total Nitrogen Concentrations in the Lower Potomac River Basin.

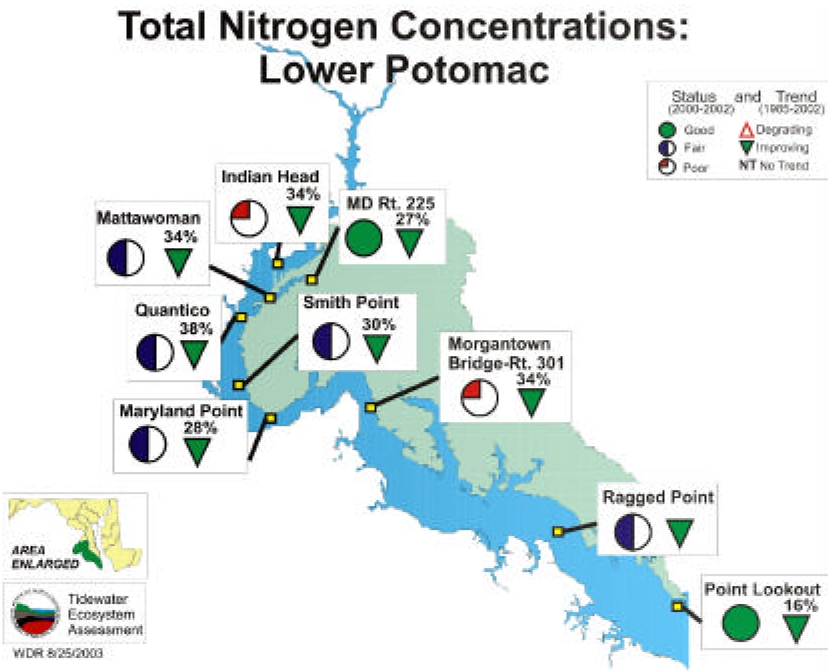


Figure LPR7 – Total Phosphorus Concentrations in the Lower Potomac River Basin.

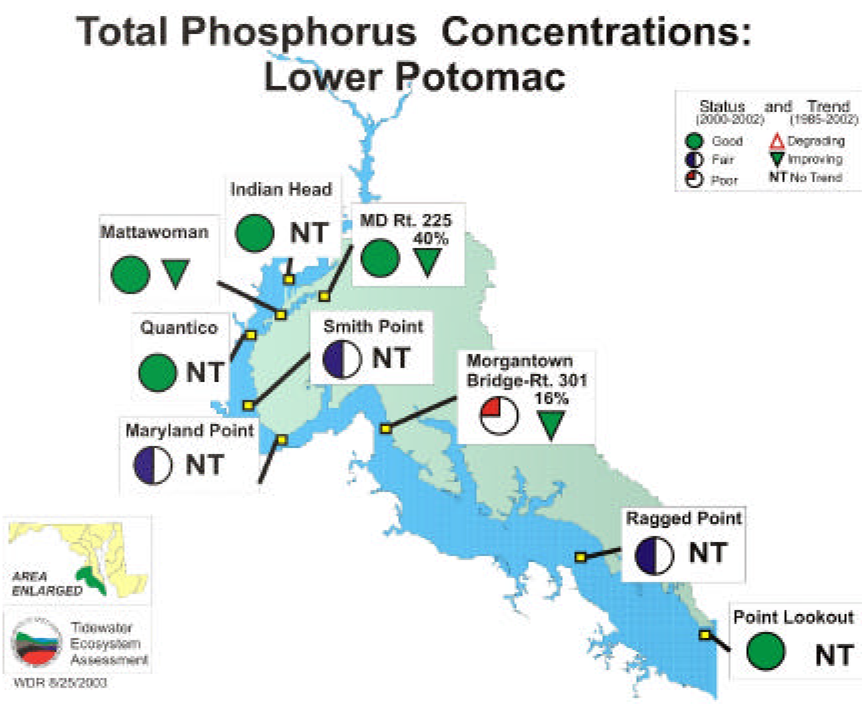


Figure LPR8 – Abundcance of Algae in the Lower Potomac River Basin.

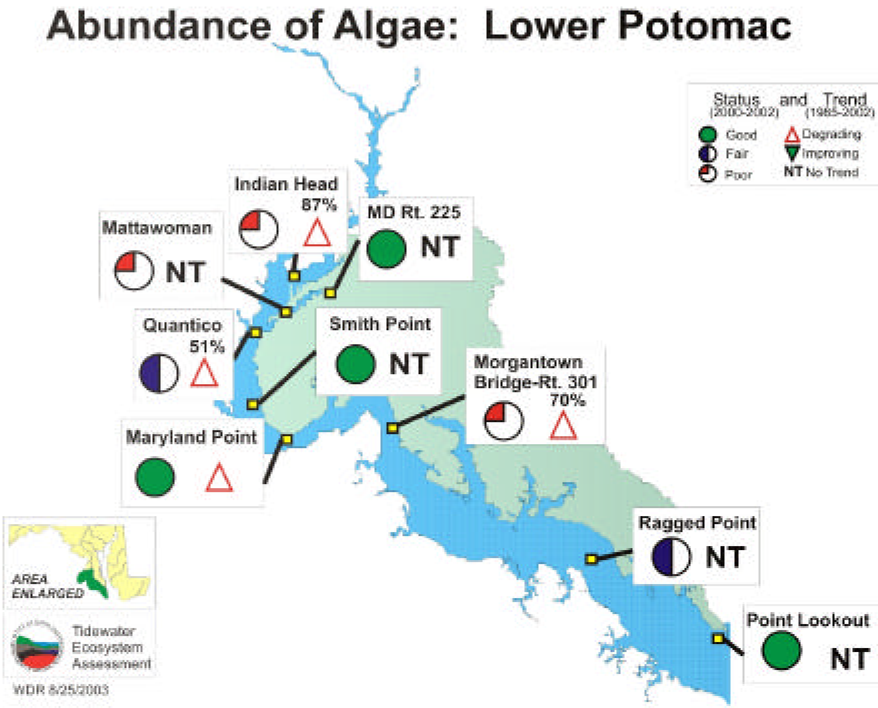


Figure LPR9 – Total Suspended Solids Concentrations in the Lower Potomac River Basin.

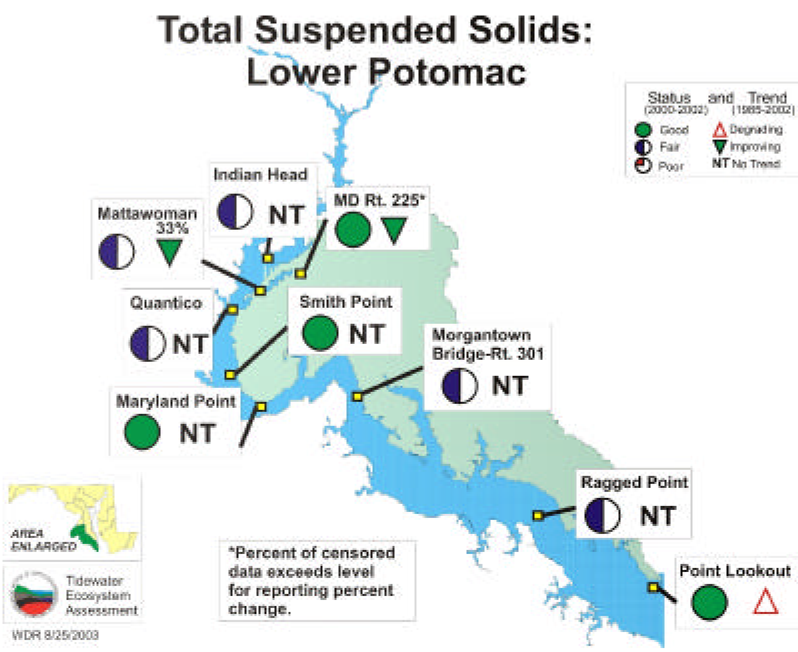


Figure LPR10 – Water Clarity (Secchi Depth) in the Lower Potomac River Basin.

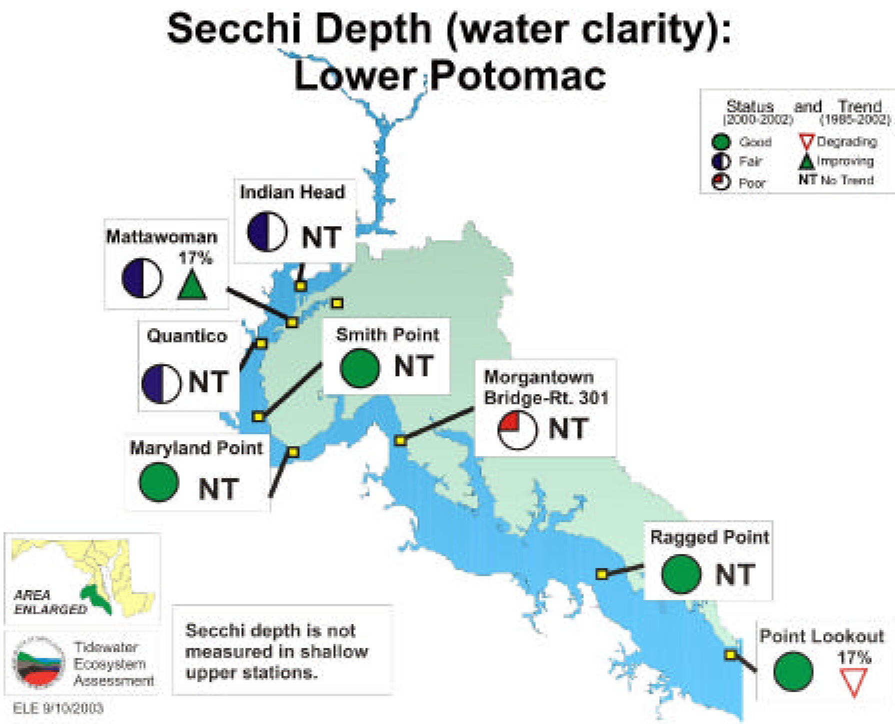
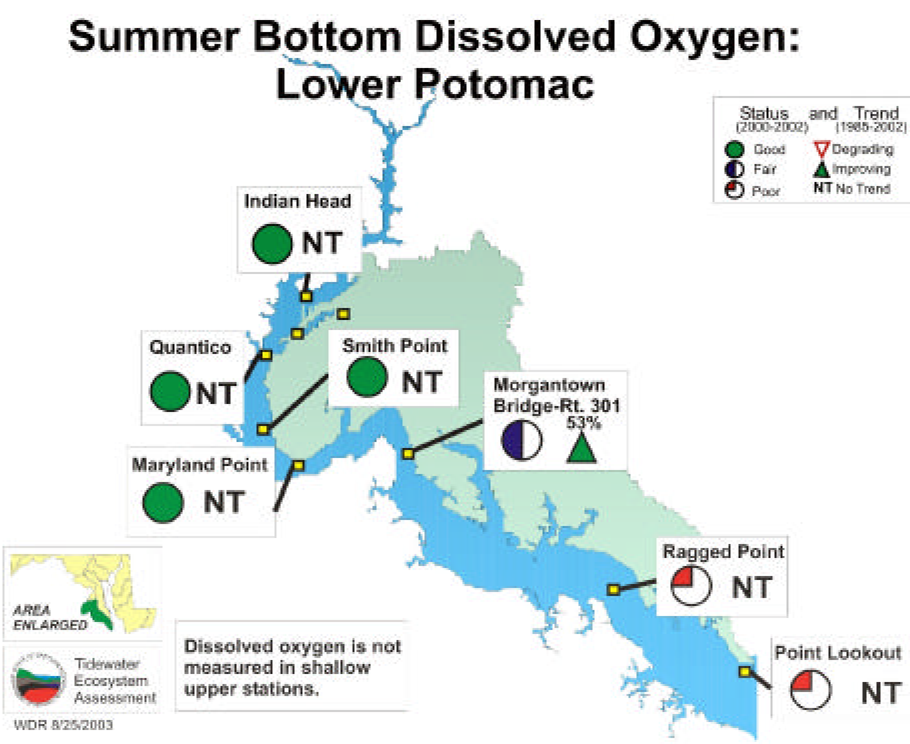


Figure LPR11 – Summer Bottom Dissolved Oxygen Concentrations in the Lower Potomac River Basin.



SAV (Bay Grasses)

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The APercent Light at Leaf@ habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older AHabitat Requirements@ of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the ATier 1 Goal@, an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

The tidal fresh Potomac River has had highly variable SAV coverage, according to the Virginia Institute of Marine Science (VIMS) annual aerial survey (www.vims.edu/bio/sav/), peaking in 1991 at 4,632 acres, or 72 percent of the 6,405 acre Tier I goal (Figure LPR12). From this high, SAV abundance decreased to a low of 1,369 acres in 1997 and rebounded in 1998, 1999 and 2000 to reach 3,879 or 61 percent of the Tier I goal. In 2001, the reported figure (1,969 acres) is down 50 percent from the 2000 number, however, it is important to remember that flight restrictions imposed after September 11, 2001 prevent VIMS from getting complete coverage. The SAV Beds fringe many of the shorelines. Ground-truthing by citizens, U. S. Geological Survey, U. S. Fish and Wildlife Service and Virginia Institute of Marine Science has found 11 species of SAV in this region, with wild celery, hydrilla and milfoil being the most reported ones. Data obtained from water quality monitoring stations located near Sheridan Point indicate that suspended solid levels pass, algae and phosphorous levels are borderline and light attenuation and percent light at leave fail the SAV habitat requirements. Nitrogen concentration is not applicable in tidal fresh regions with respect to SAV habitat requirements.

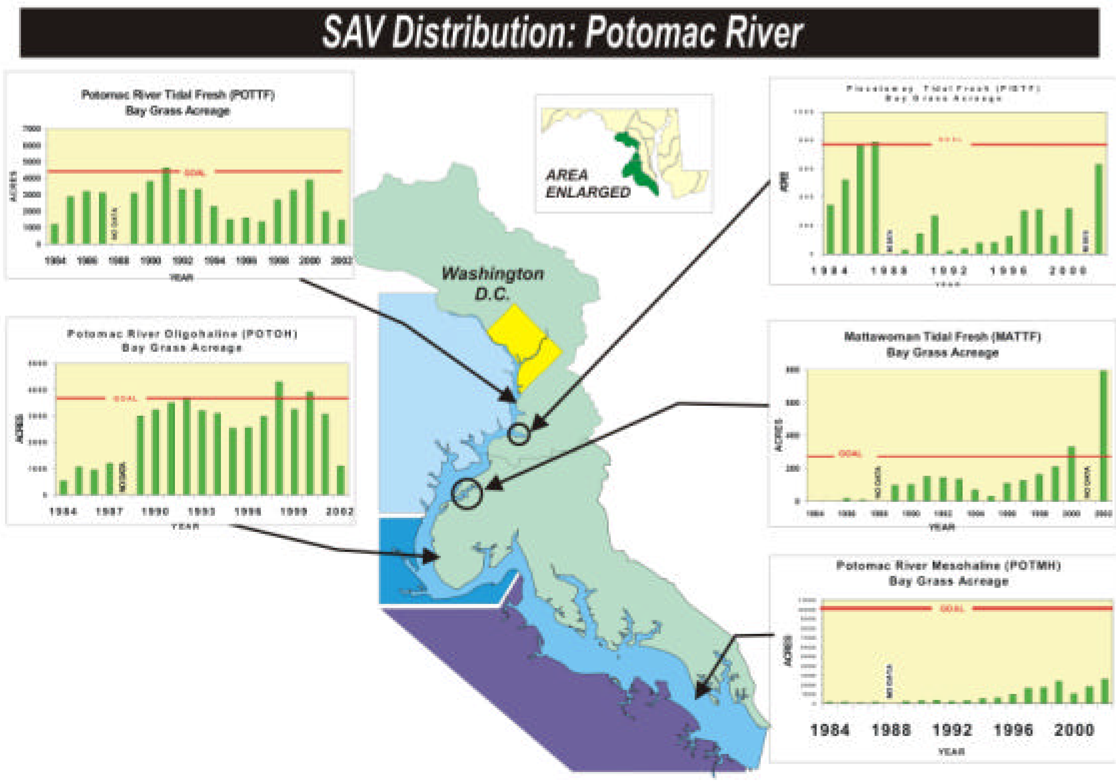
Piscataway Creek has had increases in SAV coverage since 1995, though 1999 showed a large decrease from the 1998 levels (www.vims.edu/bio/sav/). The Tier I goal for this segment is 835 acres and the 1999 and 2000 SAV coverages were 15 percent and 38 percent of this number, respectively (Figure LPR12), with the 2000 coverage being the most ever reported by the VIMS survey. In 2001, no data were obtained, again due to flight restrictions resulting from the terrorist attacks of 2001. Most of the 2000 SAV beds fringe the southern shore and the headwaters of this creek. Ground-truthing by citizens and staff from the U. S. Geological Survey has found 7 species in Piscataway Creek, listed in order of frequency recorded; hydrilla, naiads (2 species), coontail, wild celery, water stargrass, and milfoil. Water quality data from the station located near Calvert Manor indicate that algae levels and suspended solids pass in respect to the SAV habitat requirements. Light attenuation, percent light at leaf and phosphorous levels fail these requirements. Nitrogen concentration is not applicable in tidal fresh regions.

Mattawoman Creek has had steady increases in SAV coverage since 1995 (Figure LPR12), surpassing the Tier I goal (134 acres) in 1998 (163 acres), 1999 (210 acres) and 2000 (331 acres or 247 percent of the goal) (www.vims.edu/bio/sav/). No data were obtained for 2001, again due to flight restrictions. Most of the previously identified beds fringe the shoreline, upstream of Swedes and Deep Points. Extensive ground-truthing by staff from the U. S. Geological Survey, U. S. Fish and Wildlife Service and citizens from Friends of Mattawoman Creek has found hydrilla, naiads, wild celery, coontail and milfoil (in order of frequency reported) in this creek. Water quality monitoring data from the station located near Swedes Point indicate that phosphorous and suspended solids levels meet and algae levels are borderline to the SAV habitat requirements. Light attenuation and percent light at leaf fail the requirements. Nitrogen concentration is not applicable in this tidal fresh creek.

In the oligohaline (low salinity) Potomac River, between Quantico and Mathias Points, has seen fairly consistent SAV coverage since 1984, ranging from a low of 2,529 acres in 1995 to a high of 4,306 acres in 1998 (Figure LPR12), at which time the coverage exceeded the Tier I goal of 4,264 acres (www.vims.edu/bio/sav/). The 2001 coverage was 3,071 acres or 72 percent of the Tier I goal, though again these are partial data. The largest SAV beds in the Maryland portion of the river are found in Chicamuxen Creek and then fringing the shoreline to Smith Point, then fringing the shoreline from Maryland Point to just upstream of Pope Creek, including the shorelines of Nanjemoy Creek and Port Tobacco River. On the Virginia side, there are fringing beds from Shipping to Clifton Points, near the mouth of Potomac Creek, near Somerset Beach, the mouth of Chotank Creek, and fringing the shoreline around Mathias Point. Ground-truthing by citizens and staff from U. S. Geological Survey, U. S. Fish and Wildlife Service and Virginia Institute of Marine Science has found 13 different species of SAV, with the three most often reported being milfoil, wild celery, hydrilla. Water quality data from the monitoring stations near Moss and Maryland Points indicate that only algae levels meet the SAV habitat requirements, percent light at leaf and concentration of suspended solids are borderline and light attenuation and phosphorus levels fail. Nitrogen concentration is not applicable in this area.

In the mesohaline (moderate salinity) Potomac River, downstream of Mathias point to Point Lookout has had steady increases in SAV coverage since 1992 (when there was 238 acres), passing the Tier I goal of 989 acres and reaching the highest recorded level in 1999 of 2,351 acres (or 238 percent of the Tier I goal) (www.vims.edu/bio/sav/) However, the 2000 coverage was down 55 percent to 1,045 acres due to heavy springtime algal booms, but even this value exceeds the Tier I goal (Figure LPR12). In 2001, SAV coverage rebounded to 1,739 acres or 176 percent of the Tier I goal. On the Maryland side, there are fringing beds from the Route 301 bridge to Cobb Island, scattered throughout the Wicomico River and St. Clements Bay. There are a few small beds downstream from here, but no large beds until St. George Island with fringing beds through much of the lower St. Mary's River. On the Virginia side, there is a large fringing bed from Mathias Point to the Upper Machodoc Creek. Ground-truthing by citizens and staff from Patuxent River Park, Patuxent Naval Air Station, U. S. Geological Survey, U. S. Fish and Wildlife Service and Virginia Institute of Marine Science has identified 11 species with milfoil, horned pondweed and wild celery the three most frequently reported ones. Data from the three water quality monitoring stations (located at the Route 301 bridge, near Ragged Point and Point Lookout) indicates that water quality is fairly good in this area with light attenuation and nitrogen levels being borderline, while percent light at leaf, concentrations of suspended solids, algae and phosphorous pass the SAV habitat requirements.

Figure LPR12 – Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Lower Potomac River Basin.



Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For more details on the methods used in the benthic monitoring program, see http://esm.versar.com/Vcb/Benthos/backgrou.htm.

For the period 1994-2000, benthic community condition was best in the oligohaline portion of the Potomac River and worst in the mesohaline portion (Table 14). The oligohaline Potomac River exhibited a 34 percent probability of observing good benthos, although a majority of samples had benthic condition classified as indeterminate (Table 14). In the mesohaline Potomac River, most sites failed to meet the Chesapeake Bay benthic community restoration goals, resulting in a 73 percent segment-wide probability of observing degraded benthos. Sixty percent of all mesohaline segment sites showed severely impaired conditions, and 24 percent were azoic.

Both the oligohaline and the tidal freshwater Potomac River suffered primarily from excess abundance of organisms, which is often indicative of organic enrichment. In contrast, degradation in the mesohaline Potomac River was due to low abundance, low biomass, low diversity, and overall dominance by number and weight of organisms indicative of pollution. In particular, benthic biomass was severely impaired, with 83 percent of all mesohaline samples failing to meet the restoration goals for this metric. Benthic community condition in the mesohaline Potomac River was strongly correlated with stress from low dissolved oxygen. The intensity and duration of low dissolved oxygen events increase significantly with depth in the Potomac River, and so does the probability of observing degraded benthos.

Significant trends in the B-IBI were detected at two of the seven long-term benthic monitoring stations. Station 36 and 51 exhibited significantly improving conditions over the period 1985-2000 (Table 15). Benthic community status was good at these two stations and at other shallow long-term sites (Stations 43 and 47). However, the benthic community was degraded or severely degraded at the deep (>9 m) long-term mesohaline stations (Stations 44 and 52).

Improving trends at Station 36 in the tidal freshwater portion of the Potomac River can be attributed to a substantial decrease in densities of the dominant bivalve *Corbicula fluminea*, which peaked in the late 1980s. Also, oligochaete abundance (mostly *Limnodrilus hoffmeisteri*) has decreased over the long-term monitoring period. The improving benthic condition at Station 36 is most likely related to improvements in nutrient loadings. High levels of nutrients can lead to high levels of organic matter available for the benthos. Under these conditions the benthic community responds with increased abundance and biomass of opportunistic species over reference values. At Station 51 improving trends were due to improvements in total abundance, diversity, and pollution-indicative and pollution-sensitive species abundance, which suggest a positive response of shallow water benthos to improving water quality in the mesohaline Potomac River.

Figure LPR13. Number of sites failing the B-IBI and probabilities (and SE) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for low salinity habitats) for Potomac River Basin segments, 1994-2000. See Table 1 for additional information. Segments codes: TF = tidal freshwater, OH = oligohaline, MH = mesohaline.

Segment	River	Number of Sites	Sites with B-IBI<3.0	P Deg.	P Non-deg.	P Interm.
POTTF	Potomac	19	9	43.5 (10.3)	17.4 (7.9)	47.8 (10.4)
POTOH	Potomac	37	10	24.4 (6.7)	34.1 (7.4)	46.3 (7.8)
POTMH	Potomac	124	104	72.7 (3.9)	9.4 (2.6)	19.5 (3.5)

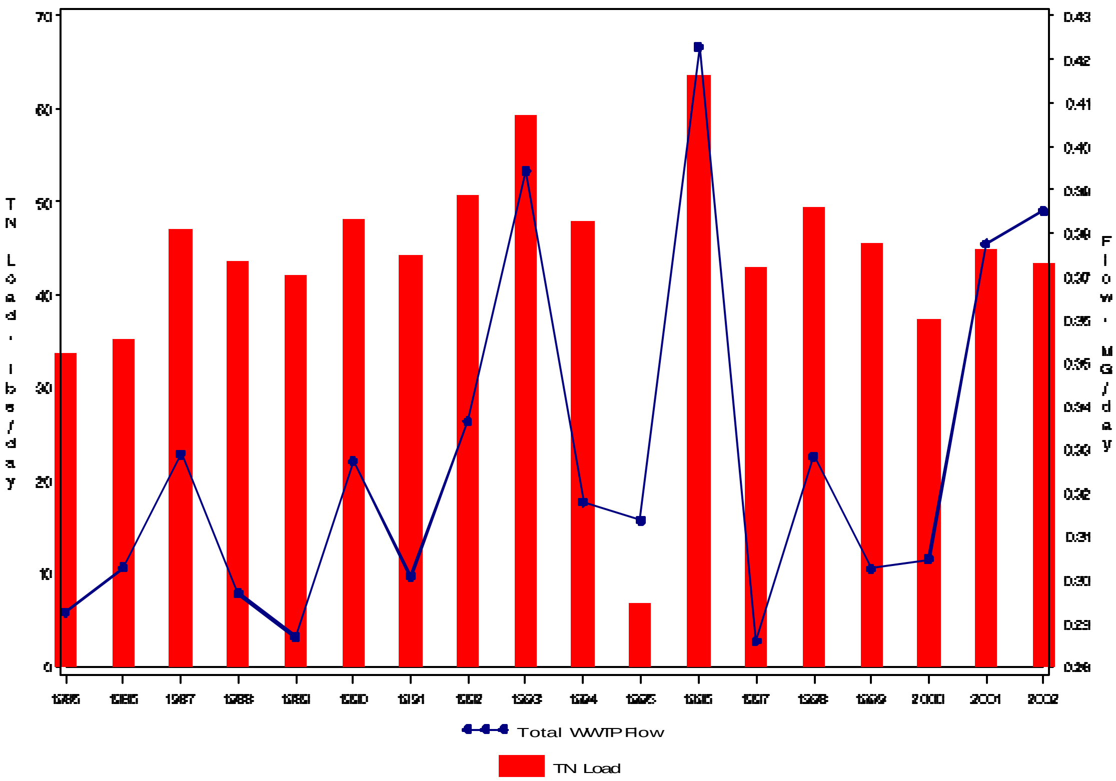
Figure LPR14. Trends in benthic community condition at Potomac River Basin long-term monitoring stations, 1985-2000. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition are based on 1998-2000 values. Initial mean B-IBI and condition are based on 1985-1987 values. NS: not significant.

Station[1]	Trend Significance	Median Slope (B-IBI units/yr)	Current Condition (1998-2000)	Initial Condition (1985-1987)
36	p <0.01	0.07	4.22 (Meets Goal)	3.20 (Meets Goal)
40	NS	0.00	3.47 (Meets Goal)	3.21 (Meets Goal)
43	NS	0.00	3.62 (Meets Goal)	3.71 (Meets Goal)
44	NS	0.00	2.33 (Degraded)	2.80 (Marginal)
47	NS	0.00	3.89 (Meets Goal)	3.89 (Meets Goal)
51	p <0.001	0.08	3.41 (Meets Goal)	2.43 (Degraded)
52	NS	0.00	1.30 (Severely Degraded)	1.37 (Severely Degraded)

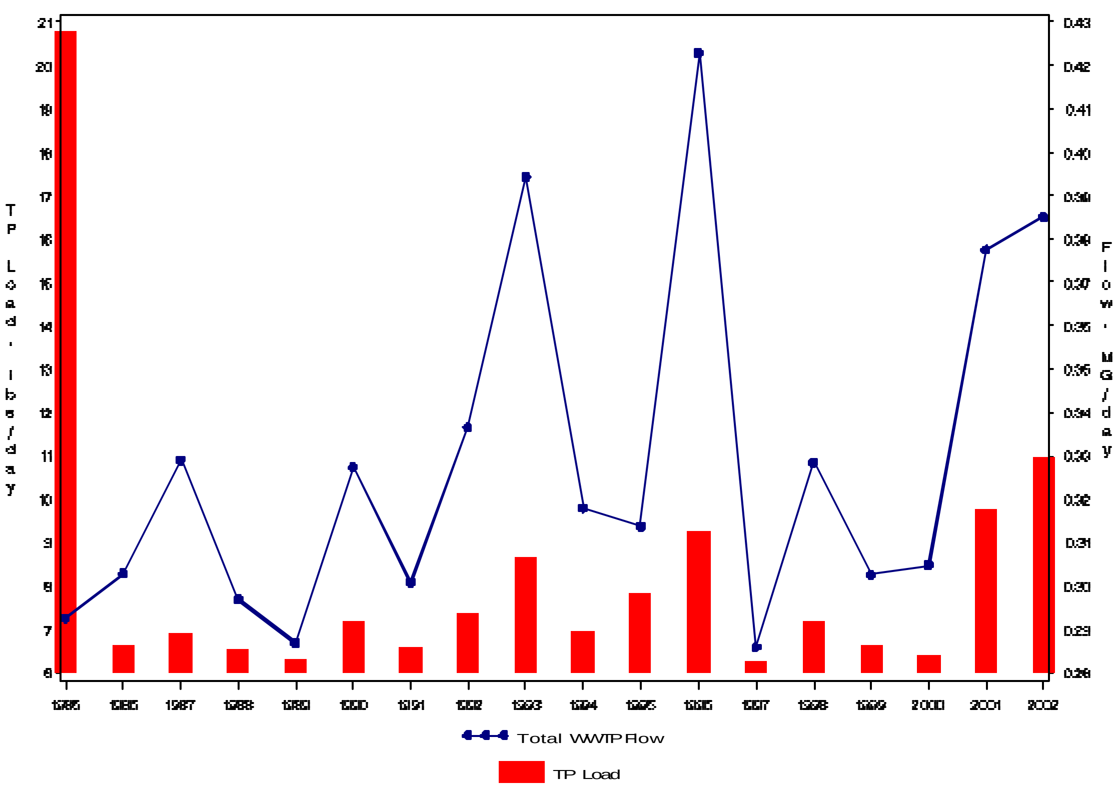
[1]Sta. 36, Rosier Bluff, tidal freshwater, 38.769781 lat., 77.037531 long.
Sta. 40, Maryland Point, oligohaline, 38.357458 lat., 77.230534 long.
Sta. 43, Morgantown above 301 bridge, low mesohaline, 38.384125 lat., 76.989028 long.
Sta. 44, Morgantown above 301 bridge, low mesohaline, 38.385625 lat., 76.984695 long.
Sta. 47, Morgantown above 301 bridge, low mesohaline, 38.365125 lat., 76.984695 long.
Sta. 51, St. Clements Island, high mesohaline sand, 38.205462 lat., 76.738020 long.
Sta. 52, St. Clements Island, high mesohaline mud, 38.192297 lat., 76.747687 long.

Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Lower Potomac River Basin

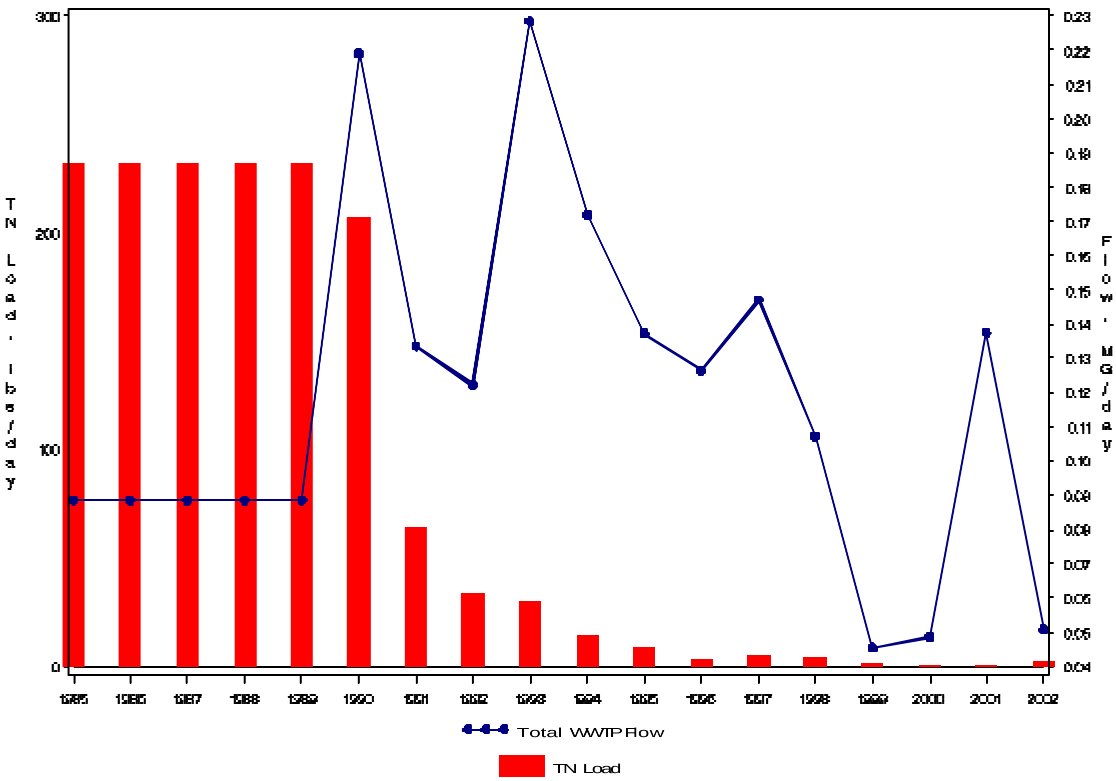
INDIAN HEAD Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



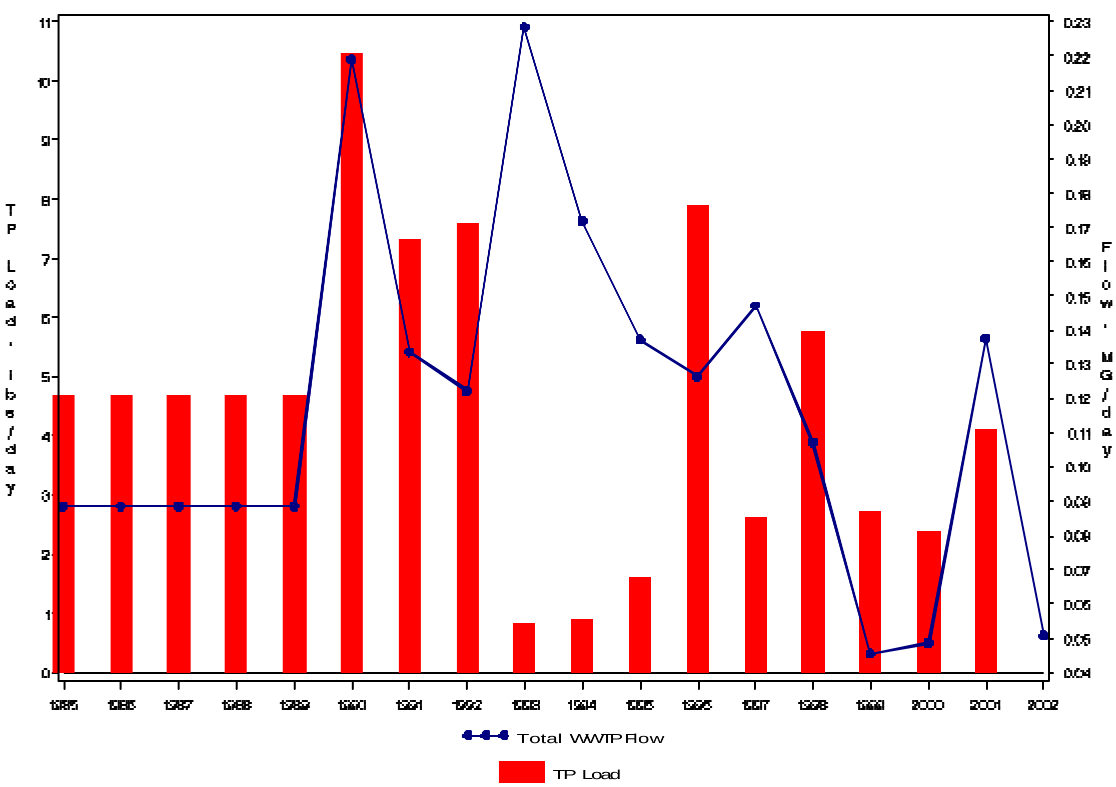
INDIAN HEAD Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



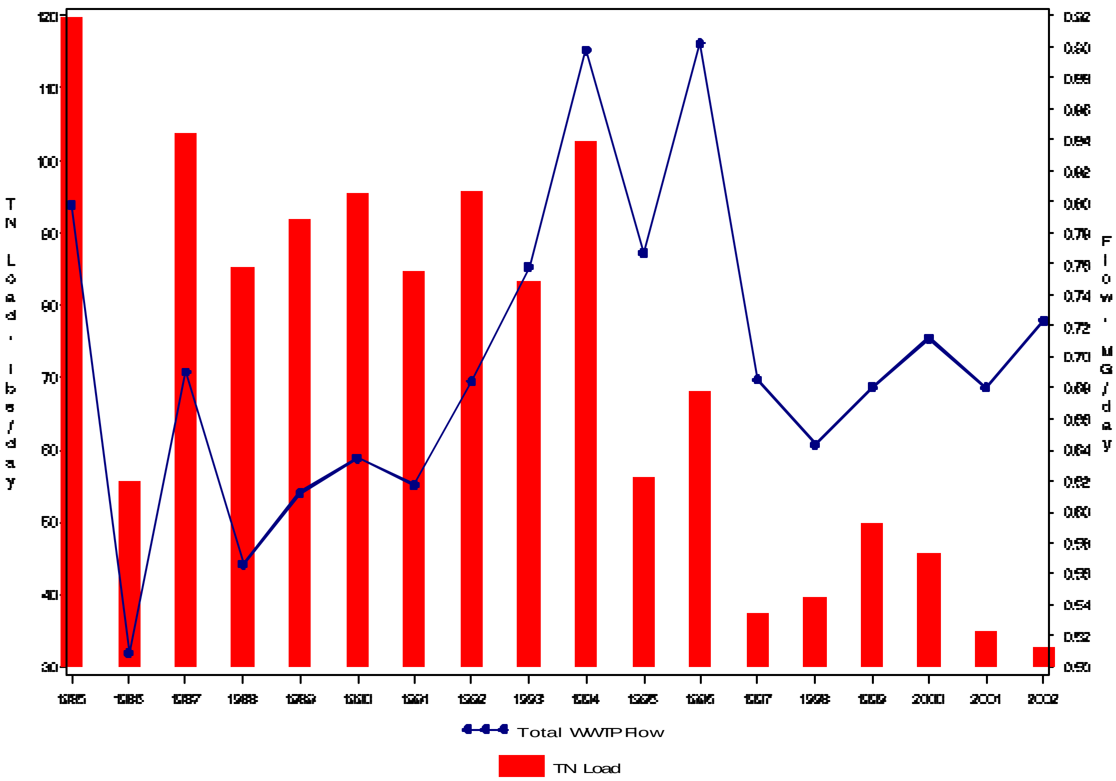
INDIAN HEAD NOS Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



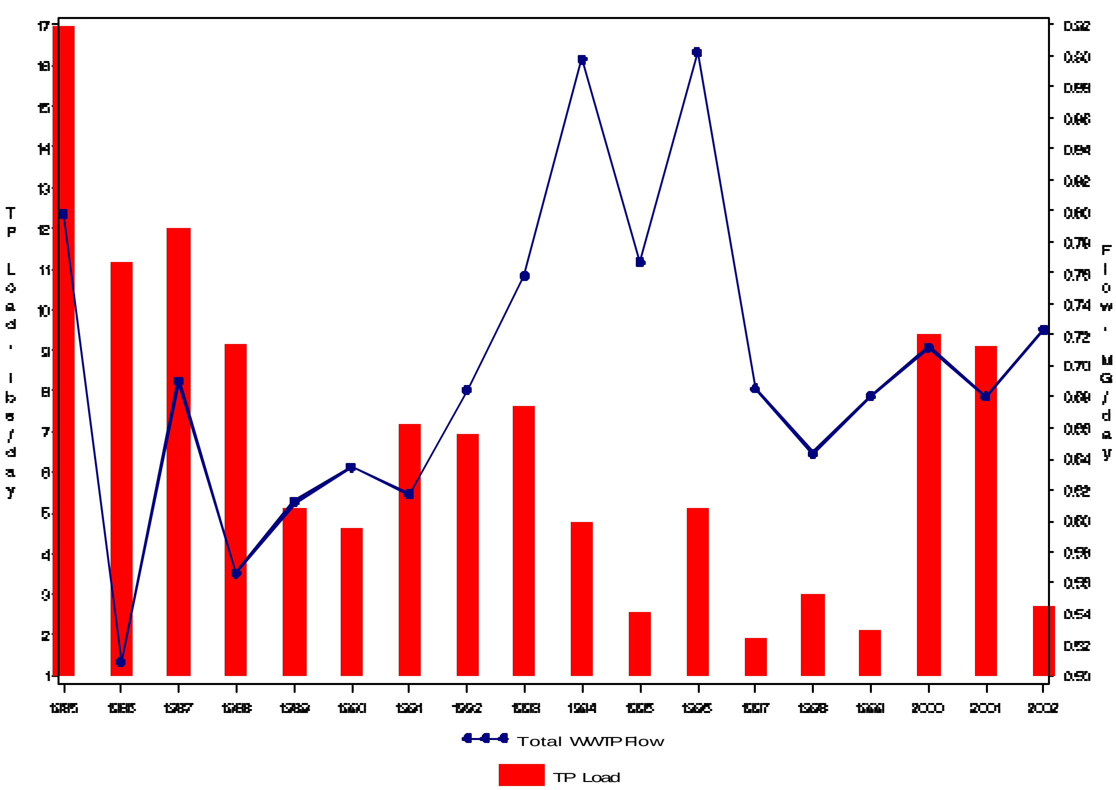
INDIAN HEAD NOS Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

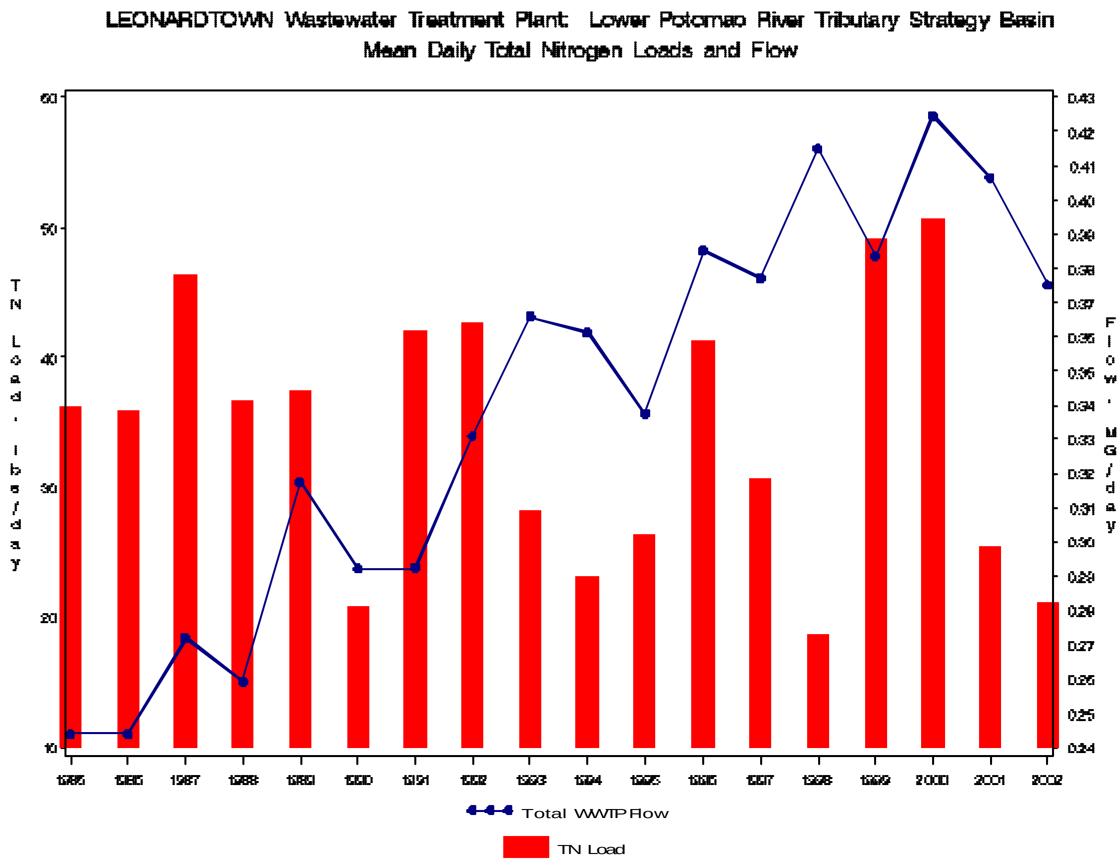


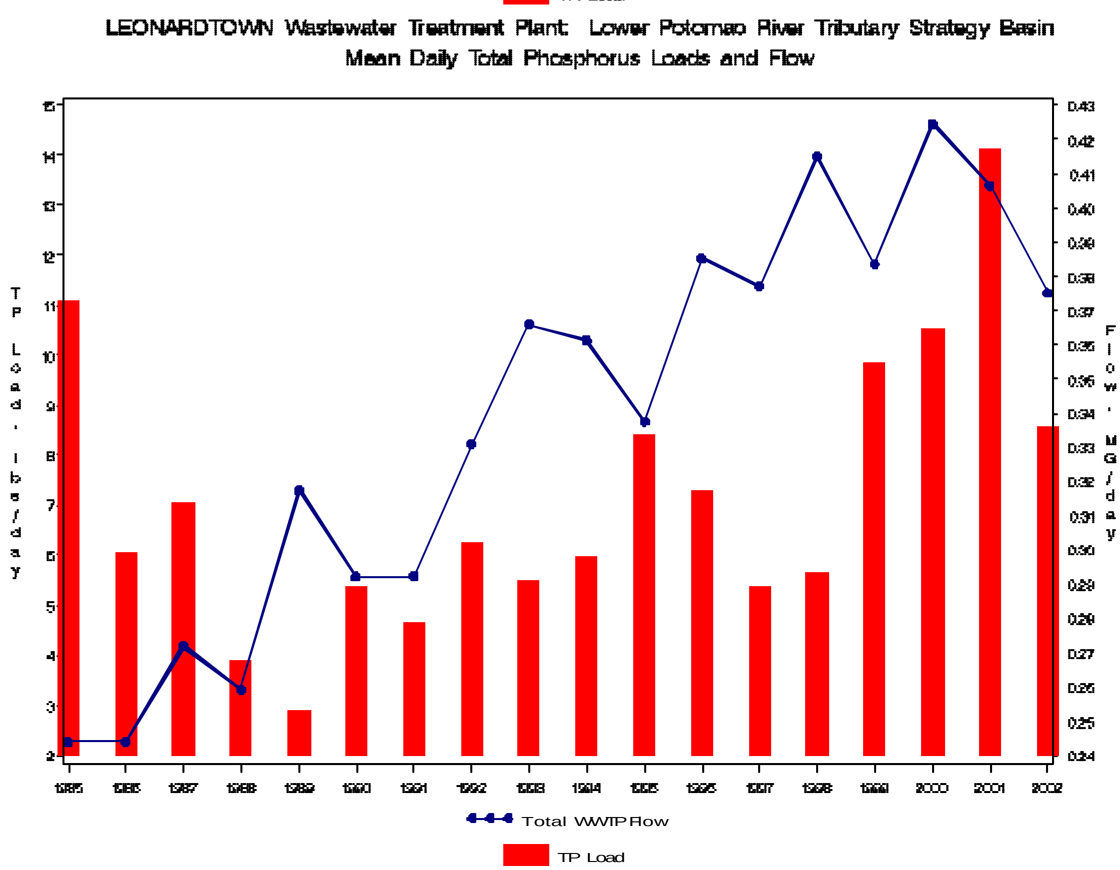
LA PLATA Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



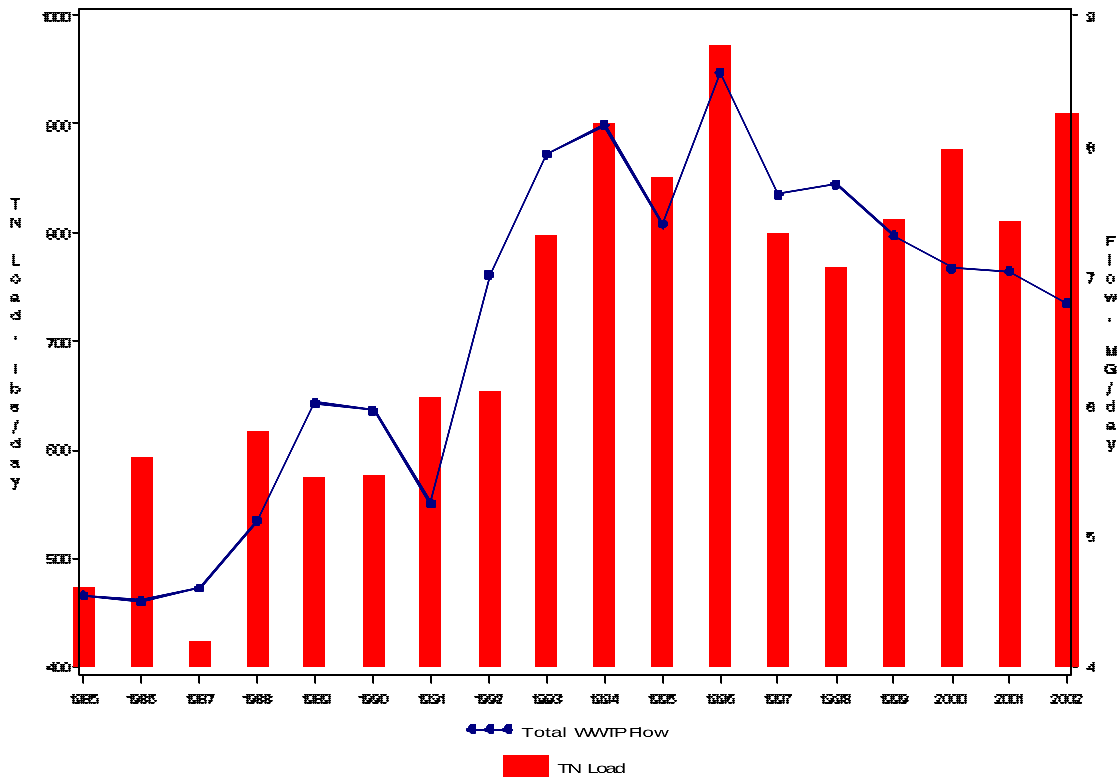
LA PLATA Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



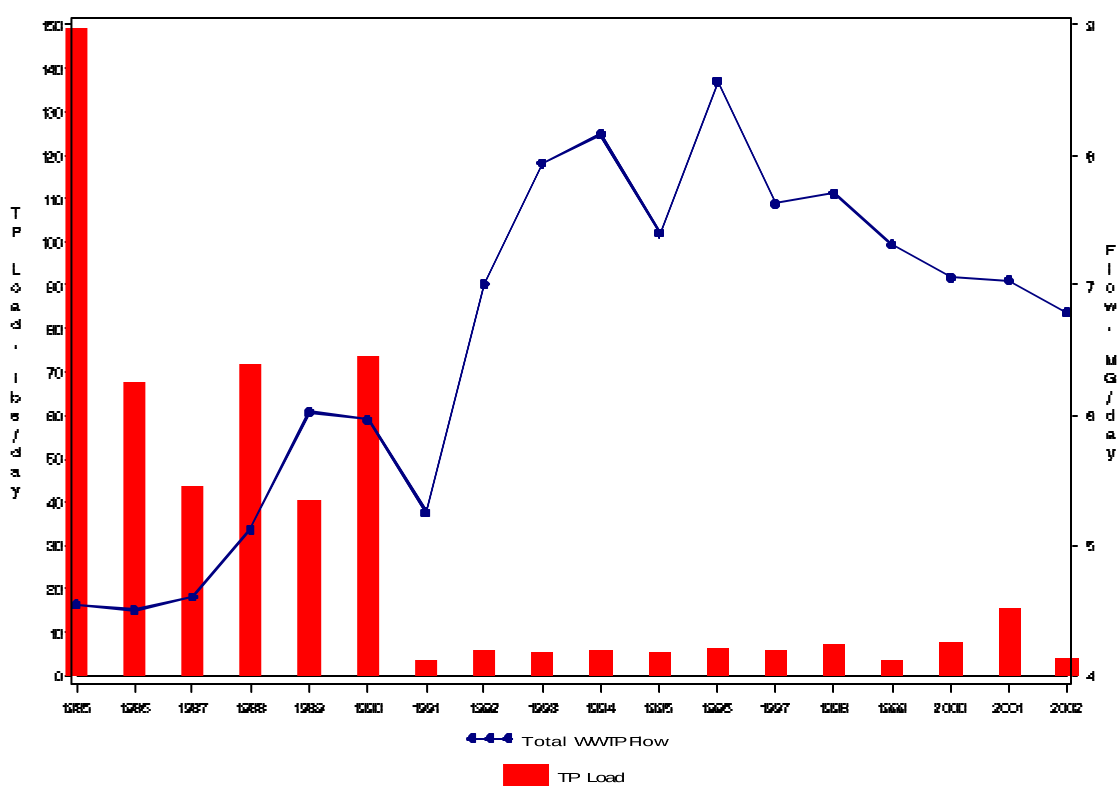

LEONARDTOWN Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow
TN Load - lbs/day
Flow - MG/day
Total WWTP Flow
TN Load


LEONARDTOWN Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow
TP Load - lbs/day
Flow - MG/day
Total WWTP Flow
TP Load

MATTAWOMAN Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



MATTAWOMAN Wastewater Treatment Plant: Lower Potomac River Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

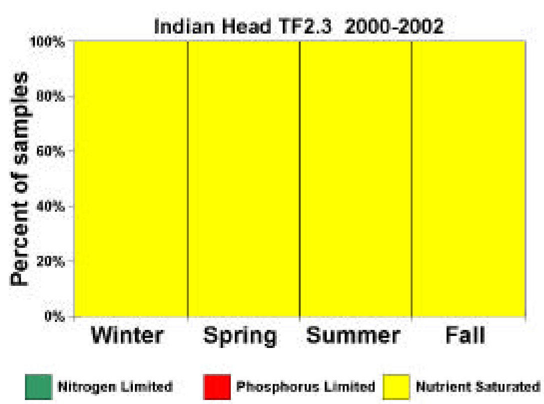


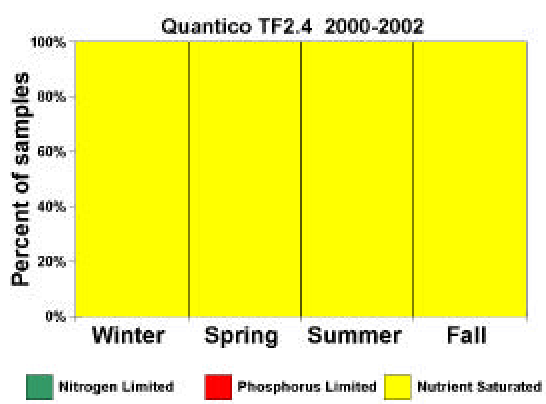
Appendix B – Nutrient Limitation Graphs for the Lower Potomac River Basin

The nutrient limitation model was used to predict nutrient limitation for the nine stations in the Lower Potomac Basin. Results for each station are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Overall, river flow is a strong factor in determining seasonal limitation patterns throughout the river. The two stations most downstream show the pattern typical of mesohaline areas, where river discharge dictates a seasonal pattern of limitation due to low light/temperatures in winter, high dissolved inorganic nitrogen/dissolved inorganic phosphorus in high river discharge in the spring, large fluxes of dissolved inorganic phosphorus fluxes from the sediments under anoxic conditions in the summer, and turnover of the water column in the fall (Fisher and Gustafson 2002).

Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

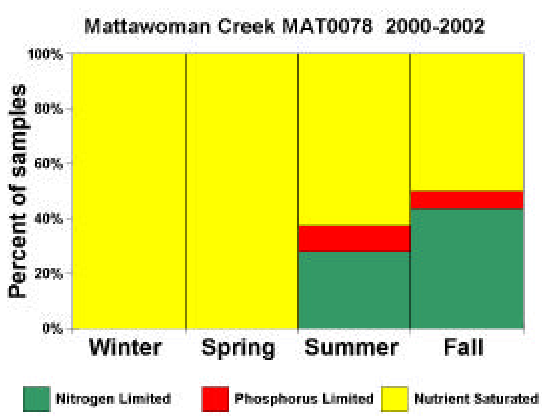
Indian Head (TF2.3) - Phytoplankton growth is entirely nutrient saturated (light limited or no limitation) at this station. Total and dissolved inorganic nitrogen concentrations are relatively poor but improving (decreasing). Total and dissolved inorganic phosphorus concentrations are relatively good. The ratio of total nitrogen to total phosphorus is decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively high. Together, this information suggests that reductions in phosphorus in all seasons will help to limit phytoplankton growth at this location. Larger nitrogen reductions will be needed to help bring the system into better balance and may lead to nitrogen limitation in the summer and fall.

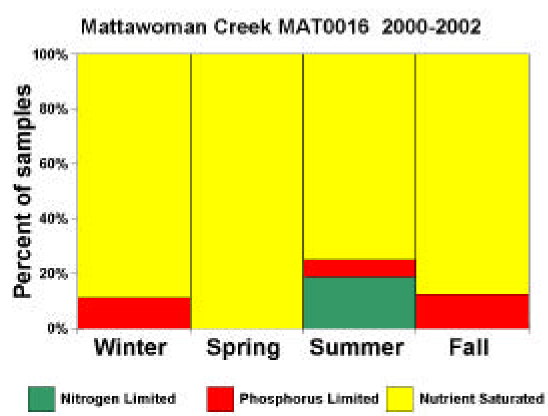




Quantico (TF2.4) - Phytoplankton growth is always nutrient saturated (light limited or no limitation) at this location. Total nitrogen concentration is relatively fair but dissolved inorganic nitrogen concentration is relatively poor; both are improving (decreasing). Total phosphorus concentration is relatively good and dissolved inorganic phosphorus concentration is relatively fair. The ratio of total nitrogen to total phosphorus is decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is moderate in winter, spring and fall and relatively low in summer. Dissolved inorganic nitrogen is high in all seasons, indicating that nitrogen limitation is less likely to occur. Together, this information suggests that reductions in phosphorus in all seasons will help to limit phytoplankton growth at this location. Larger nitrogen reductions will be needed to help bring the system into better balance and may lead to nitrogen limitation in the summer and fall.

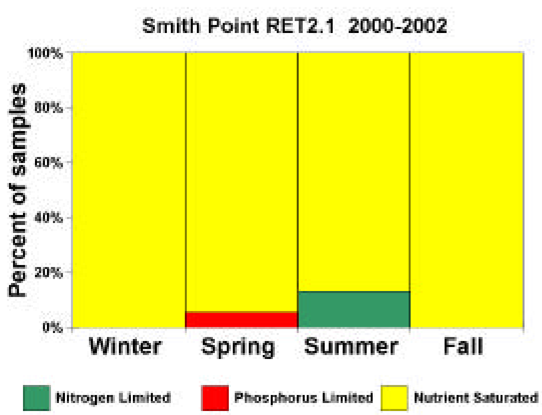
Upper Matawoman Creek (MAT0078) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) approximately 80 percent of the time. Summer and fall growth is nitrogen limited approximately 30 percent and 40 percent of the time, respectively, and phosphorus limited 10 percent and less than 10 percent of the time, respectively. Total and dissolved inorganic nitrogen and total and dissolved inorganic phosphorus concentrations are all good and improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low, indicating that phosphorus is in excess relative to nitrogen at this location. Further reductions in nitrogen will increase the occurrences of nitrogen limitation in the summer and fall. Continued reductions in phosphorus will be needed to allow phosphorus limitation to occur, especially in the spring.

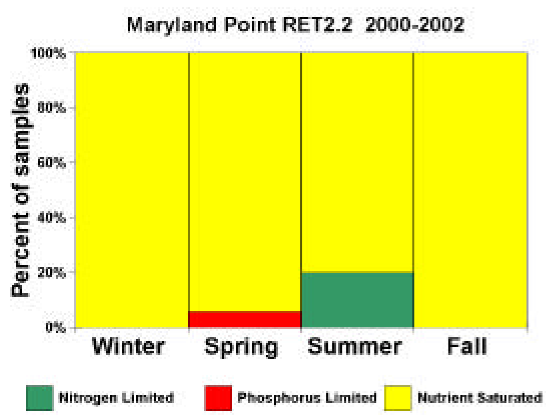




Lower Matawoman Creek (MAT0016) - On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) approximately 90 percent of the time. Winter growth is phosphorus limited 10 percent of the time and otherwise nutrient limited. Summer growth is nitrogen limited approximately 20 percent of the time and phosphorus limited more than 5 percent of the time. Fall growth is phosphorus limited approximately 10 percent of the time and otherwise is nutrient saturated. Total and dissolved inorganic nitrogen concentrations are relatively fair and improving (decreasing), and total and dissolved inorganic phosphorus concentrations are relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively high except in the summer when it is relatively low. Further reductions in nitrogen will increase the occurrences of nitrogen limitation in the summer and may allow nitrogen limitation to occur in the fall. Reductions in phosphorus will be needed to allow phosphorus limitation to occur, especially in the spring.

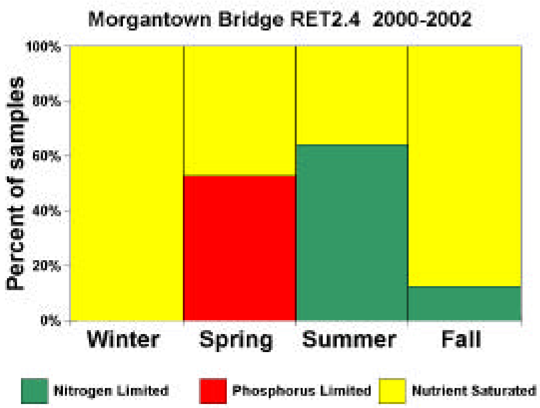
Smith Point (RET2.1) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) almost 95 percent of the time. Spring growth is phosphorus limited 5 percent of the time. Summer growth is nitrogen limited approximately 15 percent of the time. Total nitrogen concentration is relatively fair but dissolved inorganic nitrogen concentration is poor; both are improving (decreasing). Total phosphorus concentration is relatively fair and dissolved inorganic phosphorus concentration is relatively poor. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing and suggests that further reductions in nitrogen will increase the occurrences of nitrogen limitation in the summer and may allow nitrogen limitation to occur in the fall. Reductions in phosphorus will be needed to increase the occurrence of phosphorus limitation, especially in the spring.

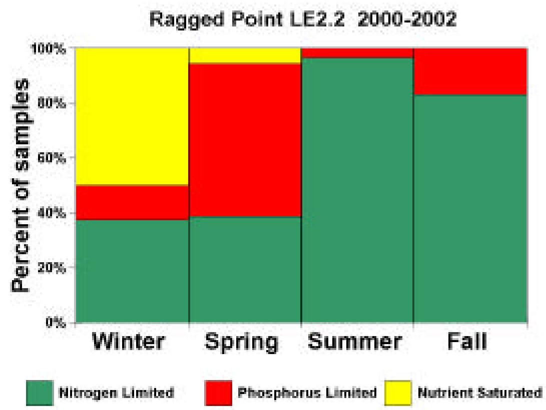




Maryland Point (RET2.2) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) approximately 90 percent of the time. Spring growth is phosphorus limited 5 percent of the time. Summer growth is nitrogen limited approximately 20 percent of the time. Total nitrogen concentration is relatively fair but dissolved inorganic nitrogen concentration is relatively poor; both are improving (decreasing). Total phosphorus concentration is relatively fair but dissolved inorganic phosphorus concentration is poor. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus suggests that further reductions in nitrogen will increase the occurrences of nitrogen limitation in the summer and may allow nitrogen limitation to occur in the fall. Reductions in phosphorus will be needed to allow phosphorus limitation to occur, especially in the spring.

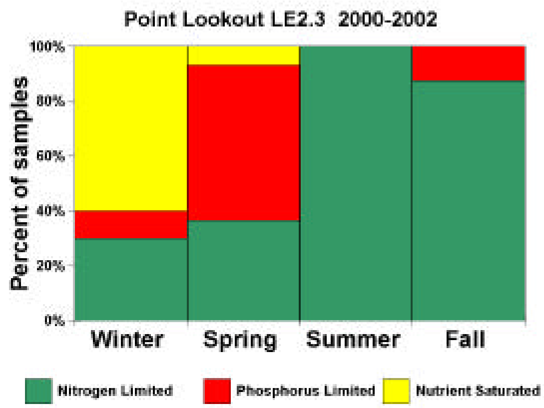
Morgantown Bridge-Rt 301 (RET2.4) - On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) approximately 60 percent of the time, and nitrogen limited and phosphorus limited approximately 20 percent of the time each. Winter growth is entirely nutrient saturated. Spring growth is phosphorus limited more than 50 percent of the time. Summer growth is nitrogen limited almost 65 percent of the time. Fall growth is nitrogen limited about 10 percent of the time. Total nitrogen, dissolved inorganic nitrogen and total phosphorus concentrations are all relatively poor but improving (decreasing); dissolved inorganic phosphorus concentration is relatively poor. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively high in the winter and spring and relatively low in the summer and fall. Further reductions in nitrogen will increase the occurrences of nitrogen limitation in the summer and fall. Additional reductions in phosphorus may allow phosphorus limitation in the winter and spring.





Ragged Point (LE2.2) – On an annual basis, phytoplankton growth is nitrogen limited approximately 65 percent of the time and phosphorus limited more than 25 percent of the time. Winter growth is nitrogen limited more than 35 percent of the time and phosphorus limited more than 10 percent of the time. Spring growth is phosphorus limited 55 percent of the time and nitrogen limited approximately 40 percent of the time. Summer growth is almost entirely nitrogen limited and otherwise is phosphorus limited. Fall growth is nitrogen limited almost 85 percent of the time and phosphorus limited more than 15 percent of the time. Total nitrogen concentration is relatively fair and dissolved inorganic nitrogen is relatively good and is improving (decreasing). Total phosphorus concentration is relatively fair and dissolved inorganic phosphorus concentration is relatively good and improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing; this ratio is relatively low in the spring and fall and very low in the summer. This information indicates that further reductions in nitrogen will further limit algal growth in the summer and fall, and may increase the occurrences of nitrogen limitation in the winter and spring. Additional reductions in phosphorus will increase the phosphorus limitation in all seasons.

Point Lookout (LE2.3) – On an annual basis, phytoplankton growth is nitrogen limited more than 65 percent of the time and phosphorus limited almost 25 percent of the time. Winter growth is nitrogen limited 30 percent of the time and phosphorus limited 10 percent of the time. Spring growth is phosphorus limited more than 55 percent of the time and nitrogen limited more than 35 percent of the time. Summer growth is entirely nitrogen limited. Fall growth is nitrogen limited more than 85 percent of the time and phosphorus limited more than 10 percent of the time. Total and dissolved inorganic nitrogen concentrations are relatively good and both are improving (decreasing); total and dissolved inorganic phosphorus concentrations are relatively good. The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low in the summer and fall and moderate to high in winter and spring. Further reductions in nitrogen will further limit algal growth in the summer and fall, and increase the occurrences of nitrogen limitation in the winter and spring. Additional reductions in phosphorus will increase the phosphorus limitation in all seasons.



Appendix C – References

Agresti, A. and B. Caffo. 2000. Simple and effective confidence intervals for proportions and differences of proportions result from adding two successes and two failures. The American Statistician 54:280–288.

Alden, R. W., III, D. M. Dauer, J. A. Ranasinghe, L. C. Scott, and R. J. Llansó. 2002. Statistical Verification of the Chesapeake Bay Benthic Index of Biotic Integrity. Environmetrics, In Press.

Fisher, T. R. and A. B. Gustafson. 2002. Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program—Nutrient/Bioassay Component—Covering the Period August 1990 – December 2001—May 2002 Report.

Ranasinghe, J. A., L. C. Scott, R. C. Newport, and S. B. Weisberg. 1994. Chesapeake Bay Water Quality Monitoring Program, Long-term Benthic Monitoring and Assessment Component, Level I Comprehensive Report, July 1984-December 1993. Chapter 5: Baltimore Harbor Trends. Prepared for Maryland Department of Natural Resources, Tidewater Ecosystem Assessments, by Versar, Inc., Columbia, Maryland.

Scott, L. C., J. A. Ranasinghe, A. T. Shaughnessy, J. Gerritsen, T. A. Tornatore, and R. Newport. 1991. Long-term benthic Monitoring and Assessment Program for the Maryland Portion of Chesapeake Bay: Level I Comprehensive Report (July 1984-April 1991), Volume I –Text. Prepared for Maryland Department of Natural Resources, Tidewater Ecosystem Assessments, by Versar, Inc., Columbia, Maryland.

Van Belle, G. and J. P. Hughes. 1984. Nonparametric tests for trend in water quality. Water Resources Research 20:127-136.

Weisberg, S. B., J. A. Ranasinghe, D. M. Dauer, L. C. Schaffner, R. J. Diaz, and J. B. Frithsen. 1997. An Estuarine Benthic Index of Biotic Integrity (B-IBI) for the Chesapeake Bay. Estuaries 20:149–158.